Geological importance of Dykes(CO2)

Top

It is well known that Earth history is punctuated by events during which large volumes of mafic magmas were generated and emplaced by processes unrelated to "normal" sea-floor spreading and subduction. These are recognized as Large Igneous Provinces. Systematic Study of dykes helps to understand and solve many geological problems. It helps to recognize Large Igneous Provinces (LIPs), particularly for the Precambrian period. Many LIPs can be linked
to regional-scale uplift, continental rifting and breakup, and climatic shifts. In the Paleozoic and Proterozoic, LIPs are typically deeply eroded. They are represented by deep-level plumbing systems consisting of giant dyke swarms, sill provinces and layered intrusions. In the Archaean the most promising LIP candidates are greenstone belts containing komatiites. Detailed study of dykes is therefore considered to be an important tool for Paleo-continental reconstructions.
Paleocontinental reconstructions are critical to provide a tectonic context for major ore deposits, the tracing of metallogenic belts between blocks, and identifying new prospective regions for mineral deposits of a wide variety of types. Dykes are equally important to understand the full context of sedimentary basins, their evolution, and their hydrocarbon reserves and potential. This will help to solve puzzle for pre-Pangean time back to 2600 Ma and provide constraints on pre-Pangean supercontinents.
Remanence can be implied,from TMI data, when interpreted 2D dykes are proposed, as a negative susceptibility will often emerge as the only way to explain the signal response. This is then usually a very good indication that the dyke may be remanent. With the advent of Full tensor Magnetic tensor gradient surveys, the stroy on this subject changes dramatically. More than half the bodies in an average survey, can no longer be described as "DYKES", and then the ability to recover from a model of the "DYKE", under each survey profile line, a magnetic unit vector that best fits the tensor response to each body, gives a direct measure of any divergence from the IGRF vector. This is a much finer response, than just saying you suspect the dyke to be remanently magnetized.
In this context, it is beholden to develop automatic tools to search the geophysical survey records, to identify and classify dyke swarms, to assist in the large scale regional interpretation of deep crustal process, with a view to improving prospecitivty for minearls and oil.

Depth estimation with Naudy Automatic Model

The Naudy Automatic Model tool scans a line dataset for dyke-like geological structures.

The tool examines the measured signal profiles along traverse lines of a dataset. It proposes geological structures at a range of depths and calculates the body response that would result from them. It then selects the set of proposed structures that would

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produce a calculated signal most closely matching the observed signal profile in the input dataset. This selected set of inferred geological structures is the Naudy Automatic Model.

Naudy Automatic Model calculates the strike of each inferred geological structure using an inbuilt automatic depth-dependent trend estimation process.

The Naudy model point dataset produced by the tool contains location, depth, width, dip, strike, susceptibility and similarity coefficient (closeness of match) of the structures.

The tool has been extended at V4.5/V5.0 during 2011/2012 to support firstly Magnetic tensor gradient signals, and to posture the tool's use for gravity gradient signal measurements. So, the generalization of the meaning of a geophysical signal to include other potential fields, is a significant development. Generally, traditional gravity measurements have not been of sufficient precision and frequency content, to be able to be used to good effect in this tool. It is the newer development of gravity tensor curvature gradients and the reducing measured wavelengths, that the Naudy method can find new application.

See Naudy Automatic Model interpretation (T43) for details about this tool.

Location of sample data for Cookbooks

Where ***install_path*** is the path of your INTREPID installation, the project directory for the *Cookbooks* sample data is ***install_path*****\sample_data\cookbooks**.

For example, if INTREPID is installed in
C:\Program Files\Intrepid\Intrepid4.5,
then you can find the sample data at
C:\Program Files\Intrepid\Intrepid4.5\sample_data\cookbooks

For information about installing or reinstalling the sample data, see "Sample data for the INTREPID Cookbooks" in Using INTREPID Cookbooks (R19).

For a description of INTREPID datasets, see Introduction to the INTREPID database (G20). For more detail, see INTREPID database, file and data structures (R05).

Advantages of the Naudy Automatic Model tool

Most aeromagnetic datasets will have more dyke-like bodies than other shapes. This gives the Naudy Automatic Model tool an advantage as a depth estimation option.

You can use this method for sources at any depth provided the corresponding profile shapes are well defined.

Where responses are superimposed on each other (overlap), the Naudy approach still appears to be reliable.

The method is very fast and can easily work on many very large surveys. For instance, a recent demonstration was made of using the tool on the complete magnetic line data sets from Botswanna. Approximately 4500 dykes could explain the majority of the observed magnetic signal for this dataset. The time taken to gwet to this point on a standard desktop computer, was around 10 hours.

In addition, this implimentation brings togetehr a few complimentary methods so that the extracted geological information is of practical direct use in building 3D

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geology models, when dyke swarms are an important component.

Important definitions

The **Observed Field** is the a) TMI or b) Tensor magnetic gradient data in the input dataset. The Naudy Automatic Model tool represents it as a black profile curve in the line profile display area

The **Calculated Field** is the TMI data that would result from the set of inferred geological structures that comprise the current model. The Naudy Automatic Model tool represents it as a red profile curve in the line profile display area.

The **Similarity Coefficient** is a measure of the similarity between the calculated field and the observed field. Its value ranges from 1 to 5, where 0 represents a perfect match and 5 a very low similarity.

The **Scanning Body** is a proposed geological structure used to calculate a value for the calculated field. INTREPID records the similarity coefficients for the scanning body along the line at each depth. It uses this array of similarity coefficients to locate solutions.

The width of the scanning body increases for greater depths. The starting dip of the scanning body is normally 90° (vertical), but a range can be used as well. The calculated dip is senstive to noise in the observed signal, so is adjusted for admissible values.

How the Naudy Automatic Model tool works

The Naudy Automatic Model tool scans a line dataset for dyke-like geological structures.

1 The tool examines the Total Magnetic Intensity (TMI) profiles along traverse lines of a dataset. It proposes geological structures at a range of depths and calculates the TMI that would result from each proposed structure.

It compares the calculated TMI of the proposed geological structures with the observed TMI and assigns a similarity coefficient to the proposed structure at that point. INTREPID repeats this process along the line at different depths until it has a set of similarity coefficients for each depth along the line.

2 INTREPID estimates the trends in the data by comparing positions of maxima and minima in adjacent lines. From these estimates, it calculates the strike of each inferred geological structure.

3 The Naudy Automatic Model tool estimates directional trends in the data by comparing positions of maxima and minima in adjacent lines. It estimates the trends at a number of depths. From these estimates, it calculates the strike of each inferred geological structure.

4 INTREPID locates minima in the array of similarity coefficients. It records each minimum as a Naudy solution with a similarity coefficient equal to the similarity coefficient at that point. A graphical representation of this process is given when you use the SCAN button.

5 INTREPID then resamples the solutions, rejecting those with a similarity coefficient greater than a threshold you specify and selecting the best solution where there is a cluster of them.

6 INTREPID creates the model from the set of solutions. The characteristics of the scanning body at the location and depth of a solution become the characteristics of

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an inferred geological structure at that point. The position of a solution corresponds to the midpoint of the top of the inferred geological structure.

7 The Naudy model data includes location, depth, width, dip, susceptibility and similarity coefficient of each inferred geological structure.The Naudy Automatic Model tool can optionally refine the model using an inversion process. INTREPID varies the properties of each inferred geological structure and calculates the corresponding TMI. It selects the set of property values whose TMI profile has the best least squares fit with the observed TMI profile,

8 The Naudy Automatic Model tool saves the description of the final set of inferred geological structures as a point dataset.

9 After you have calculated the model for the dataset (and refined it if required), you can examine it in the plan view or include it in a hard copy composition. Some of the dyke-like structures inferred by the Naudy Automatic Model tool will continue across many lines.

10 Inversion is used to check and improve the initial solution. This is done in two stages, A. moving the bodies and checking admissible solutions. B. Purturbing the dip, width to improve the fit.

11 The option to join solutions togetehr to produce 3D Dykes is available after the initial profile solutions are calculated and saved to a point dataset. This is termed “Export worms to Geomodeller”. A CSV file, suitable for examination in EXCEL, is produced, with an order list of Dykes, that are formed according to your preferences.

If an inferred geological structure continues through adjacent or nearby lines you can have high confidence that it corresponds to a physical structure. (If there are distortions in the waveform, inferred geological structures may be discontinuous on adjacent lines but continued in nearby lines.)

If an inferred geological structure does not appear to continue in nearby lines, you should have doubts about its correspondence to a physical structure.

Suggested ways of examining the solutions graphically, so that an integrated geological interpretation can be developed include -

- Use Geomodeller to import the CSV file. See Tutorial K for Geomodeller.
- Use MapInfo/ArcMap and import the CSV and treaty them as geological structural observations.
- Use EXCEL to examine, sort and select any dykes of intrest.

Structures inferred by the Naudy Automatic Model tool

Characteristics of the dyke-like structures

Dyke-like bodies are thin, near-vertical sheet-like geological structures. See "Shapes of source bodies" in Estimating Source Depth—Overview (C01) for further general discussion about shapes.

The Naudy Automatic Model tool as currently implemented is designed to detect and determine depth to two-dimensional dyke-like bodies whose

- Thickness is less than their depth,

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- Strike extent (extent in the direction of their strike) is at most 5 times their depth,
- Corresponding TMI profile shapes are well-defined.

Characteristics of the plate-like structures whose edges can be found

Plate-like bodies are thin, near-horizontal sheet-like geological structures.

Naudy Automatic Model can detect and estimate the depth to the edge of thin plate-like structures. This method may also be useful for detecting the edge of faulted or sheared blocks where the relative vertical movement is small.

Characteristics of the step-like structures whose edges can be found

Step-like structures show a sudden change of magnetic response. Examples include

- Contact between large bodies, such as between granite and surrounding rocks or
- Uplifted blocks at the site of a fault, such as a Horst-Graben.

Depth estimation worked example (mineral exploration)

This case study shows how a minerals explorer can use the INTREPID Naudy Automatic Model tool to infer a set of dyke-like geological structures from a magnetic survey.

Overview

In the case study, we will first calculate the Naudy Automatic Model from the total magnetic intensity (TMI). This will yield the best estimates for bodies at intermediate depth.

We then demostrate joining the point solutions to form 3D dykes that can extend for several kilometers. Summary linear solutions are also available.

You can go on to calculate the model from the first vertical derivative (1VD) data. This will yield the best estimates for shallow bodies.

In each case we will examine the resulting point dataset overlaid on a grid of the source data (TMI and 1VD respectively).

The case study dataset

We have provided a sample survey near Broken Hill, New South Wales, Australia, for use in the case study. The *Cookbook* (Cookbook) sample datasets include this dataset. It normally resides in the directory ***install_path*/sample_data/cookbooks/interp_min** and consists of:

- A line dataset called **BrokenHill..DIR**, which is the survey for analysis.
- Grid datasets created from the TMI and 1VD fields in **BrokenHill..DIR**. We have performed reduction to the pole on these grids. The grids are named **BH_TMI_grid** and **BH_1vd_grid** respectively.
- Naudy model point datasets produced using the instructions in this case study. The datasets are named **BH_TMI_Naudy..DIR** and **BH_1vd_Naudy..DIR**. We have provided these datasets so that you can compare your results after following the case study.

We recommend that you use the names **BH_TMI_Naudy1** and **BH_1vd_Naudy1** for the output datasets when you follow the case study.

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Steps in the case study

Determine the average flying height

1 Examine the **`Clearance`** field of the dataset to determine the average flying height. You can specify this as a parameter in the Naudy Automatic Model tool. Your results will be more reliable and will not contain above-ground solutions! To examine the field, highlight (click) the **`BrokenHill..DIR`** dataset in the **Filename** panel in the INTREPID Project Manager. Choose the **Statistics** tab, then highlight the **`groundClearance`** field and choose **Calculate**. INTREPID will display statistics or a histogram for the field.

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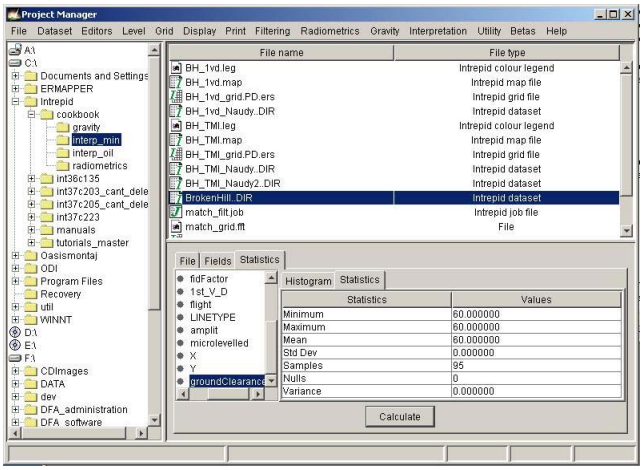
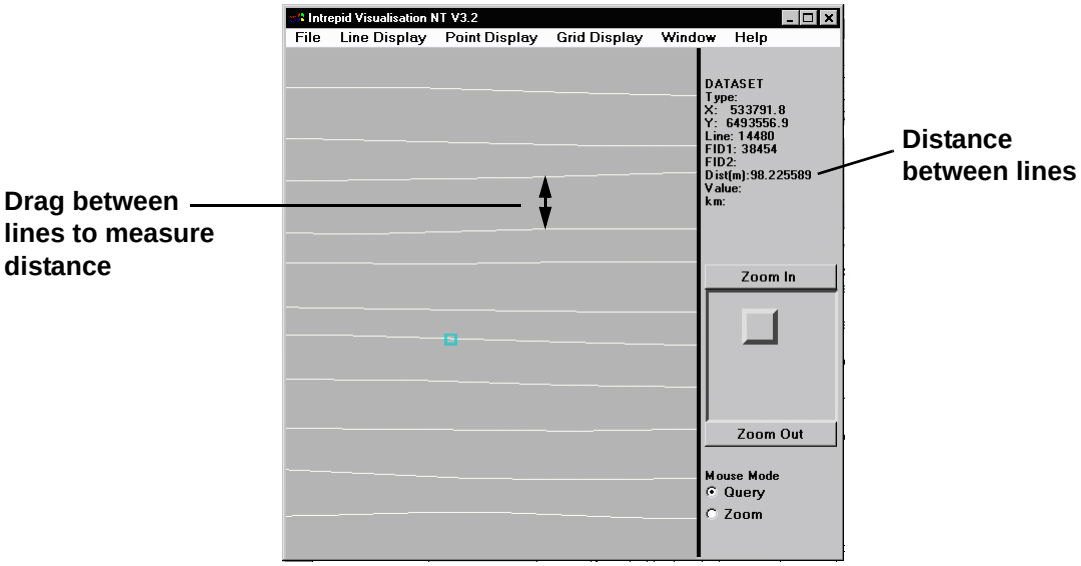
INTREPID displays statistics for the field.



In our case, the **Clearance** field has been corrected and has a mean value of 60 metres.

2 Optional: Determining the average line spacing of the dataset. If you do not know the average line spacing of the dataset, you can measure it with a visualisation tool. To do this using *Windows,* launch the Visualisation tool. Load the line dataset **`BrokenHill..DIR`**. Select **Zoom** mouse mode. Zoom in on an area that appears to have regular line spacing. Select **Query** mouse mode. Left-mouse-button-drag from one line to the next and read the line separation from the **Dist (m)** report field. Repeat this measurement with one or two other line pairs until you have a reliable estimate for the average line spacing.



The average line spacing of the **`BrokenHill`** dataset is 100 m.

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Tip: *The following table contains a summary of the input and output data for this section of the exercise.*

Function	Dataset or Field	Marker file suffix (*Windows*)
Naudy Automatic Model process		
Line dataset containing survey	**BrokenHill**	**..DIR**
Signal Field for calculating Naudy model	**microlevelled**	**..LINE**
Output Naudy model point dataset	**BH_TMI_Naudy1**	
Visualisation		
Solution Naudy mode point dataset for display of model	**BH_TMI_Naudy**	**..DIR**
Signal field for point colour	**Depth_Bin_No**	**..PNT**
Signal field for point size	**Depth_Bin_No**	**..PNT**
Grid for overlay in display of model	**BH_TMI_grid**	**..GRID**
Hard Copy Composition		
Output hard copy specification file for presenting the Naudy model	**BH_TMI1.map**	n/a
Solution hard copy specification file provided for presenting the Naudy model	**BH_TMI.map**	
WORMS, 3D Dykes		
Solution of dykes sorted by 3D continuity, strike, solution quality	**bh_dykes**	csv
Linear summary of each dyke	**Summary_bh_dyke**	csv

Tip: *It is optional to also usean Oasis database for the Line dataset*

Launch Naudy Automatic Model; Specify the input.

3 From the **Project Manager Interpretation** menu, choose **Auto Model**. This will launch the Naudy Automatic Model tool. From the **File** menu, select **Load Line** dataset. Specify the Data[1] type to be TMI. Specify **BrokenHill..DIR** as the input dataset (**BrokenHill** if you are using *UNIX*). Specify **microlevelled** as the input signal field.

1. This is important– INTREPID uses different parameters and filters for TMI and 1VD.

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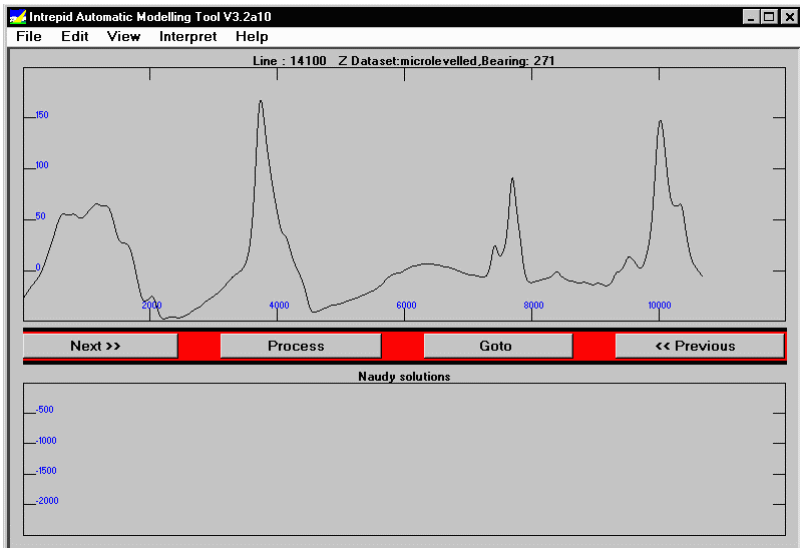
INTREPID displays the first line of the survey in the Naudy Automatic Model window. The upper panel shows a profile of the line with location along the horizontal axis and TMI value along the vertical axis.



Specify the output dataset.

4 From the **File** menu, choose **Save Model As**. Specify **`BH_TMI_Naudy1`**[1] as the output Naudy model point dataset.

Turn on* Always Regenerate Model *mode.

5 From the **Interpret** menu, turn on (click) **Always Regenerate Model**. In this mode, each time you view a different line, INTREPID will recalculate the model for that line. This is analogous to 'Auto-recalculate' mode in a spreadsheet such as *Excel*. It involves more processing but avoids confusion for novice users.

6 From the **Interpret** menu, choose **Earth's Magnetic Field & Clearance**. The default is to calculate the Earth's magnetic field using the dataset locations. Leave it as it is. Check the **Remove survey clearance from depth** option, and enter the average **Clearance** which you calculated earlier using the Project Manager. Choose **OK**.

1. We provide an identical solution dataset called **`BH_TMI_Naudy`**.

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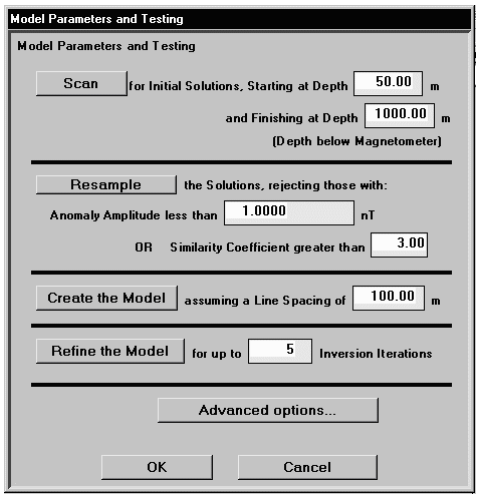
Set the model parameters.

7 From the **Interpret** menu, choose **Set and Test Parameters**.



For A. Scan: the default scan **Starting at Depth** of 50 m approximates the average clearance of 60 m that you checked earlier, so no change is required.

Specify **Finishing at Depth** of 1000 m.

For B. Resample: Leave the defaults as they are.

For C. **Create the Model**: Specify **Line Spacing** as 100 m.

Choose **OK**.

Set the advanced options.

8 From the **Interpret** menu, choose **Advanced Parameters**. For **Dip Search Strategy**, select the **Use Naudy-Derived Dips** option. For **Body Strike Options**, select the **Calculate Trends** option. Choose **OK**.

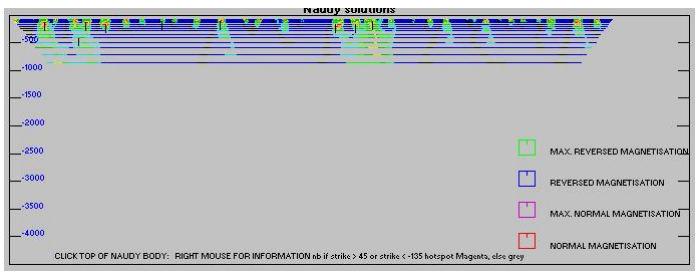
Tip: *The* **Width of the Naudy operator** *corresponds to the size of the anomalies we are seeking. When you calculate the model for 1VD you will specify a much smaller Naudy operator because the 1VD data is sharper. The value of this parameter needs to be wide enough to cover an anomaly but narrow enough to avoid overlapping and incorporating adjacent responses.*

Tip: *Calculating trend information enables INTREPID to assign strike values to the inferred geological structures. This improves the quality of the solutions. If you are processing 1VD data, INTREPID will use different filters and parameters.*

Tip: *If you are already satisfied with the parameters you can skip steps 8 and 9, or even steps 9–14.*

Calculate Naudy solutions for the first line.

9 From the **Interpret** menu, again choose **Set and Test Parameters**. Choose **Scan**. INTREPID will calculate and display the Naudy solutions for the first line in the lower panel of the Naudy Automatic Model window.



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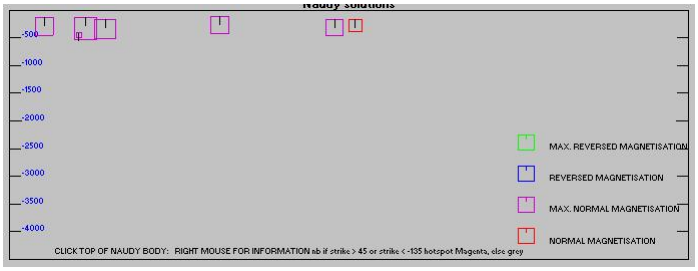
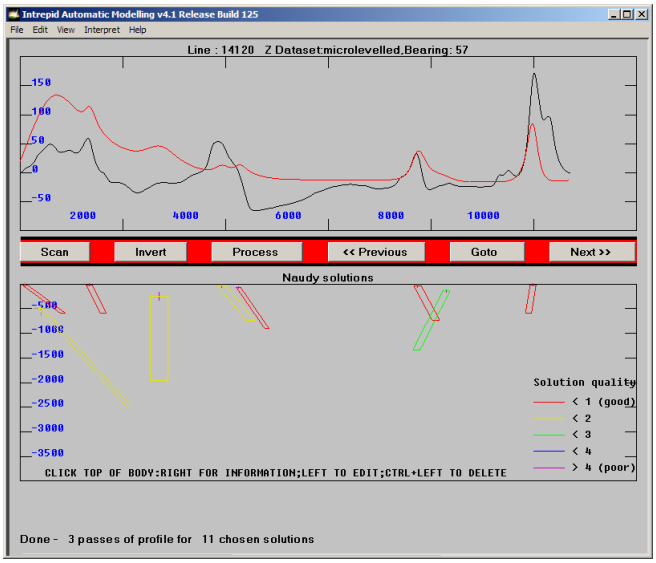
Resample the solutions for the first line.

10 Choose **Resample**. INTREPID will refine the set of solutions, rejecting those with a high (poor) similarity coefficient. INTREPID displays the refined set of solutions.



Create the model for the first line.

11 Choose **Create the Model** and then **OK**. INTREPID calculates and displays the Naudy model in the lower panel of the Naudy Automatic Model window. Choose **Next >>** and **<< Previous** to view the model for a number of lines. Return to the second line, 14120. (The model for the first and last lines of a dataset will be less reliable than the rest.)



The Naudy model display shows the inferred geological structures colour coded according to similarity coefficient. You can

- Zoom in and out,
- Report information about individual bodies,
- Edit parameters of individual bodies,
- Delete individual bodies.

Tip: Refining the model: *The Naudy Automatic Model tool can refine models by varying the position, depth, size, angle and susceptibility of inferred geological structures. It chooses the variations that most closely fit the calculated field to the observed field. We recommend this process for datasets whose structures are well separated, but not where there are overlapping structures.To test refinement, choose* **Refine the Model** *in the* **Model Parameters and Testing** *dialog box and then examine the results in the window. To automatically refine the model when it is calculated, turn on* **Automatically Invert when Calculating Model** *in the* **Advanced Model Options** *dialog box.*

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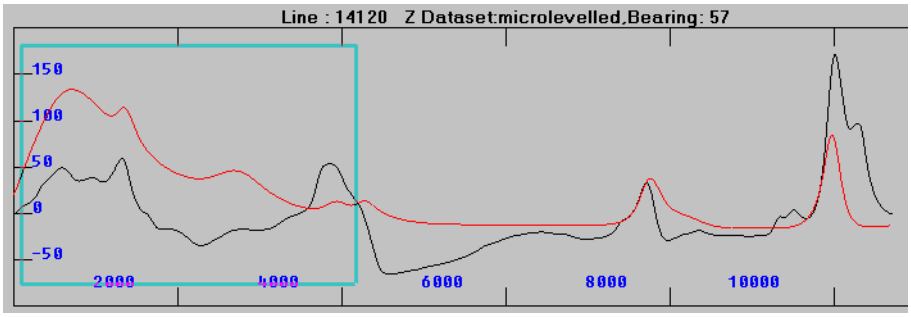
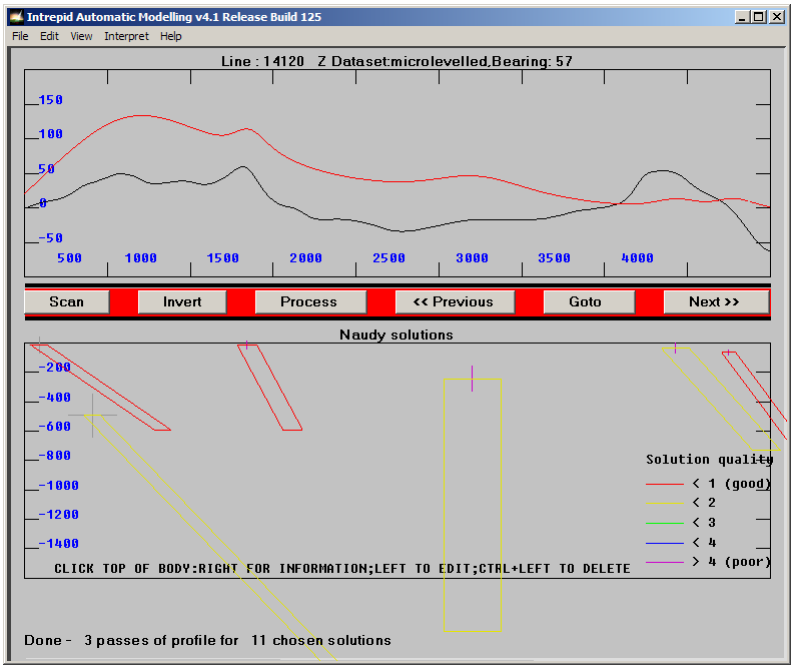
Zoom in.

12 Zoom in on a section of the line to show more detail. Use the left mouse button to define a zoom area ('rubber band stretch').



INTREPID will zoom the display to the area you define.



Zoom out.

13 *Zoom out to display the whole line.*

Double click the upper (line profile) panel.

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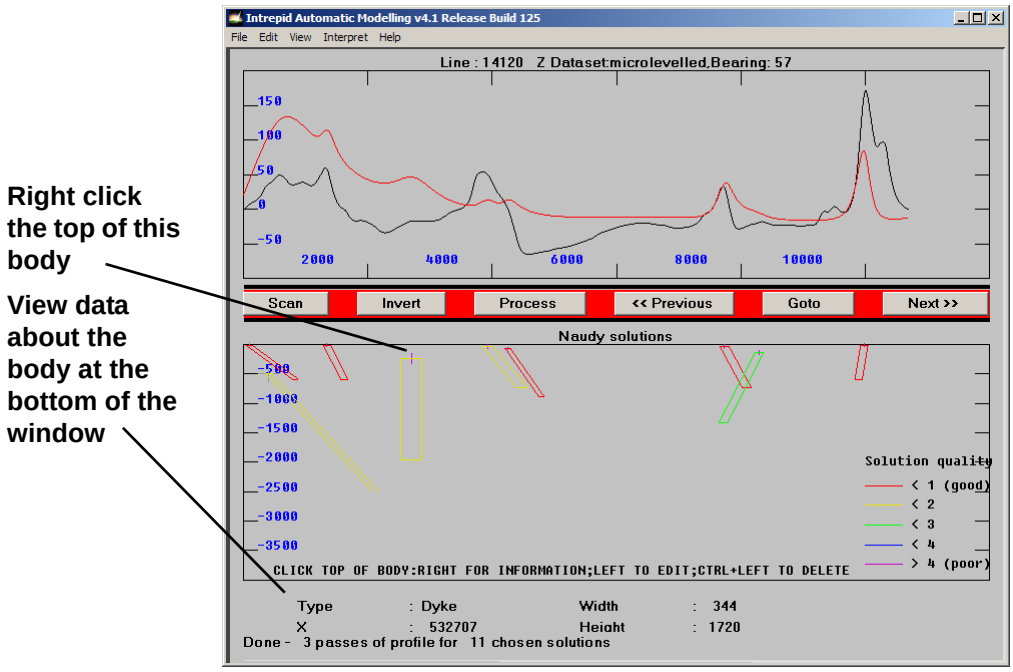
Query an inferred geological structure.

14 Display information about one of the inferred geological structures. Click the top of the structure using the right mouse button. INTREPID displays information about the body at the bottom of the window.



Tip: *You can also delete an inferred geological structure or edit its specifications. To delete a structure from the model, hold down CTRL and left button click the top of body. To edit a structure, left button click the top of it. INTREPID displays an edit dialog box. You can classify or group the structures according to your own system using the* **`GroupID`** *field. INTREPID will record the numbers you enter in the output Naudy model point dataset.*

View other lines.

15 *Examine the model for a number of lines.*

We recommend that you examine the first few lines, a couple of lines from the middle, and a couple from the end of the dataset. Use **Next**, **Previous** and **Goto** in the Naudy Automatic Model window. When you choose **Goto**, INTREPID displays a dialog box with a list of line numbers for selection.

Tip: *If you are adjusting parameters during this examination process, ensure that* **Always Recalculate** *in the* **Interpret** *menu is turned on.* INTREPID *will recalculate the model for each line you subsequently view.*

Tip: *In the* **Automatic Modelling Options and Testing** *dialog box, you do not need to choose* **Scan and Resample** *before* **Create the Model** *unless you wish to examine the Naudy solutions. When you choose* **Create the Model**, *INTREPID automatically calculates and resamples the solutions.*

Tip: *Before viewing the model for other lines, you must close the* **Model Parameters and Testing** *dialog box.*

Tip: *Whenever you view a new line, INTREPID automatically calculates the model with the current parameters:*
If the line currently has no model OR
If the line has a model and the **Always Recalculate Model** *option is on.*

Tip: *You can automatically create the model with the current settings for some or all lines. See the next step for details.*

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Specify a fresh output dataset and calculate the model for all lines

16 *When you are satisfied with your choice of options, clear the model for all lines and then create a fresh Naudy model for the lines you require.*

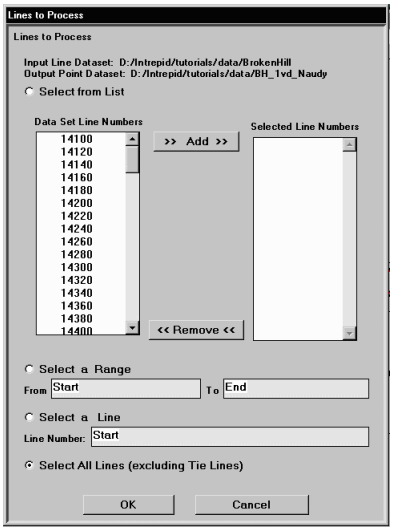
Tip: *You may have calculated models for some lines using earlier parameters that you specified during testing. To delete these depth solutions and start with a clean model before commencing your final processing, choose the '***Clear Model for All Lines***'. option.*

From the **Edit** menu, choose **Clear Model for All Lines**. Any models generated during the testing phase will now be deleted.

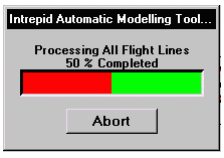
Create the model for the lines required. In this case study, we will create the model for all lines.

Choose **Process** from the Naudy Automatic Model window.

Ensure that the **Select All Lines** option is selected and then choose **Accept**.



INTREPID will calculate the model for the lines specified. This will take a few minutes.



Tip: *In order to keep the exercise simple, we have removed the tie lines from this dataset. When you process all or selected lines INTREPID will automatically exclude tie lines if it can identify them. For this to occur, you must have a line type field where the acquisition lines for process have type 2. (The conventional type number for tie lines is 4.) You must assign this field to the* **LineType** *alias. INTREPID will then only process lines whose type is 2.*

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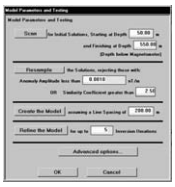
Examine the model using plan view

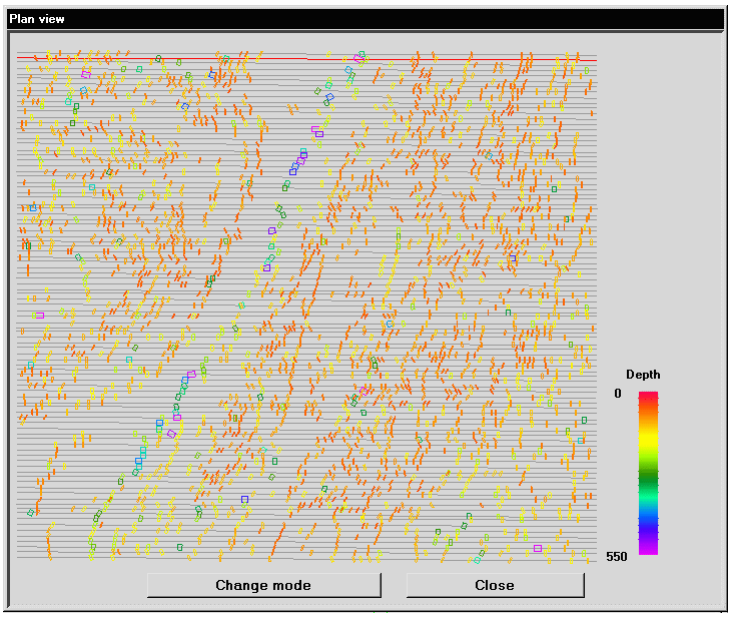
17 *Set the maximum depth for the model to 550 m then examine the Plan view of the model.*

Choose **Set and Test Parameters** from the **Interpret** menu. Change **Finishing at Depth** to **550** m. INTREPID uses this parameter to control the colours in the plan view.



Choose **Plan View** from the **View** menu.

INTREPID displays a plan view of the model with the inferred structures shown as coloured bars across the lines. The direction of each bar indicates the strike of the corresponding inferred structure. If the legend is titled '**Similarity**', choose **Change Mode** to switch to **Depth** mode.



Tip: *This display always shows all of the bodies in the model. The depth range that you set controls the colours only. If you set the finishing depth to a ridiculously low value, all of the bodies would appear purple. The current version of the tool only allows you to change the finishing depth.You can change the maximum depth for display and see the plan view again. Simply close the plan view and repeat step 16 using a different finishing depth.*

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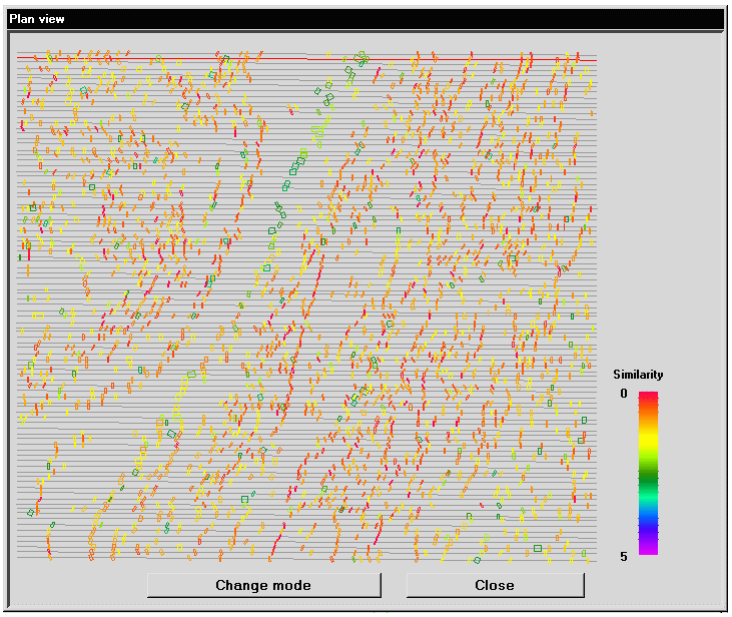
18 *Display plan view in Similarity mode.*

If the plan view window is not open, choose **Plan View** from the **View** menu. If the legend is titled '**Depth**', choose **Change Mode** to switch to **Similarity** mode.

In this view, the inferred structures are colour coded according to their similarity coefficient.



Choose **Close** when you have finished examining the plan view.

Export the 3D bodies to Geomodeller

New to V4.5 is the ability to export the dykes as 3D worms to a CSV file, prior to using these observations as structural controls while doing a 3D geology interpretation is say Geomodeller (see Tutorial K).

For mineral exploration, cohecrent 3D surfaces, as thin bodies, or dykes, form a very important part of the geology landscape.

Even if the magnetic response just appears to be dyke-like, methoids to extract the zone of higher susceptibility in a sheet like body, can be significatly helpful.

A copper (CU) project, that has had a phase change, next to a heat anomaly, can sometimes have a quite distinctive sheet like response in the magetic record.

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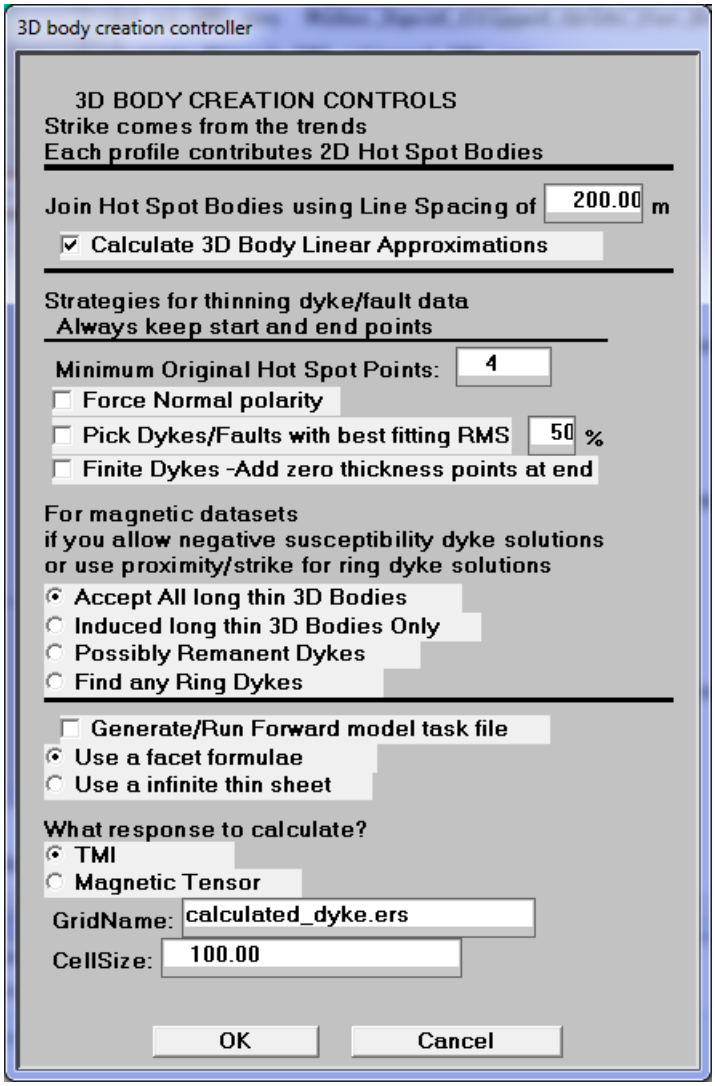
3D body creation controller
3D BODY CREATION CONTROLS
Strike comes from the trends
Each profile contributes 2D Hot Spot Bodies
Join Hot Spot Bodies using Line Spacing of 200.00 m
Calculate 3D Body Linear Approximations
Strategies for thinning dyke/fault data
Always keep start and end points
Minimum Original Hot Spot Points: 4
Force Normal polarity
Pick Dykes/Faults with best fitting RMS 50 %
Finite Dykes -Add zero thickness points at end
For magnetic datasets
if you allow negative susceptibility dyke solutions
or use proximity/strike for ring dyke solutions
Accept All long thin 3D Bodies
Induced long thin 3D Bodies Only
Possibly Remanent Dykes
Find any Ring Dykes
Generate/Run Forward model task file
Use a facet formulae
Use a infinite thin sheet
What response to calculate?
TMI
Magnetic Tensor
GridName: calculated_dyke.ers
CellSize: 100.00
OK
Cancel

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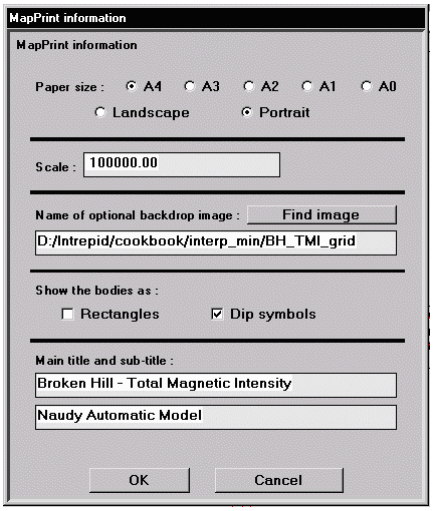
Create a MAPCOMP hard copy file to show the model

1 Output the model to a MAPCOMP file. INTREPID's Hard Copy Composition tool can display and print the results.

From the **File** menu, choose **Export Model to MAPCOMP**. Specify the composition as follows

Element	Value
Mode	**Map of Naudy bodies**
Page size	A4
Orientation	**Portrait**
Scale	100000
Optional backdrop image	**BH_TMI_grid** (use Find Image to locate it)
Show the bodies as	**Dip Symbols** On, **Rectangle** Off
Title	**Broken Hill – Total Magnetic Intensity**
Subtitle	**Naudy Automatic Model**



Choose **OK**. Specify **BH_TMI1** as the name of the hard copy specification (**.map**) file (We provide the solution file **BH_TMI.map**). Later in this example you will print or print preview this hard copy composition.

Exit from Naudy Automatic Model

2 Exit from the Naudy Automatic Model tool.

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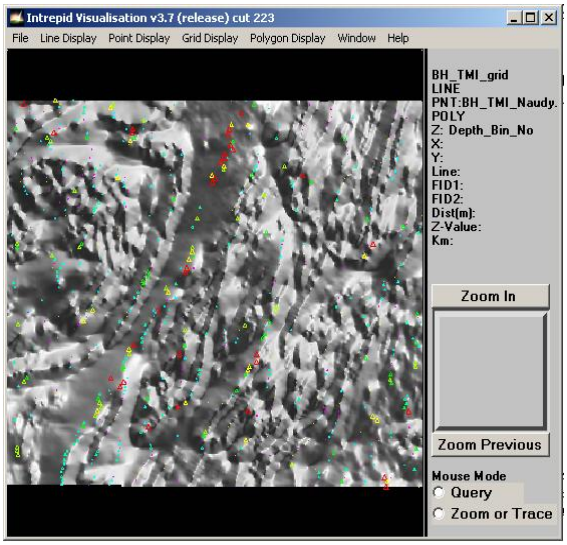
View the model overlaid on a sun angle grid.

3 *View the Naudy model point dataset overlaid on a sun angle grid of the TMI data.*

Launch the Visualisation tool. Load the grid **`BH_TMI_grid`**. Display it using sun angle[1].Load the point dataset **`BH_TMI_Naudy`**. Specify the field **`Depth_Bin_No`** for both the colour and size of points. Examine the display.

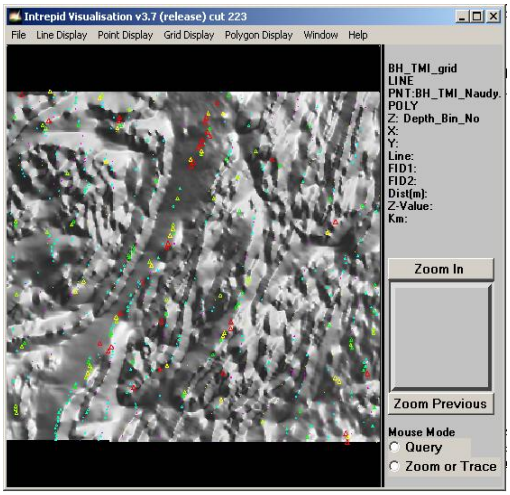


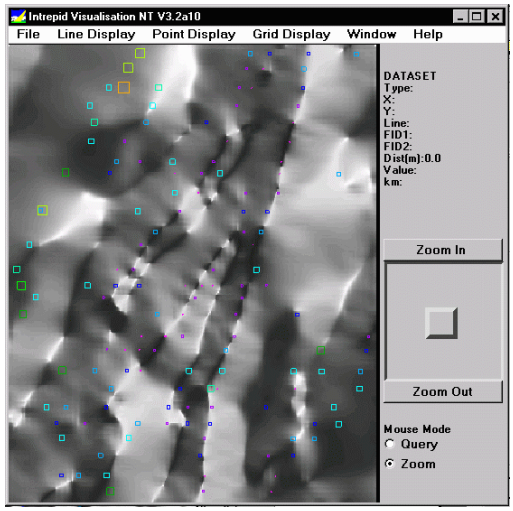
Tip: *The field* **`Depth_Bin_No`** *results from classification of the depth values into groups (bins) as if you were preparing a histogram. For visualisation, using bin number instead of depth value helps to achieve a balanced pseudocolour distribution, removing the influence of extreme values.*

Zoom in.

4 *Zoom in on sections of the display for closer examination.*

Select **Zoom** mouse mode and zoom in on a region suitable for assessing the quality of the model.





5 Exit from the Visualisation tool when you have finished examining the images. Now switch to the INTREPID Project Manager.

---

1. When you examine the 1VD data, use **Declination** 315, **Inclination** 30 and **Vertical Exaggeration** 1000.

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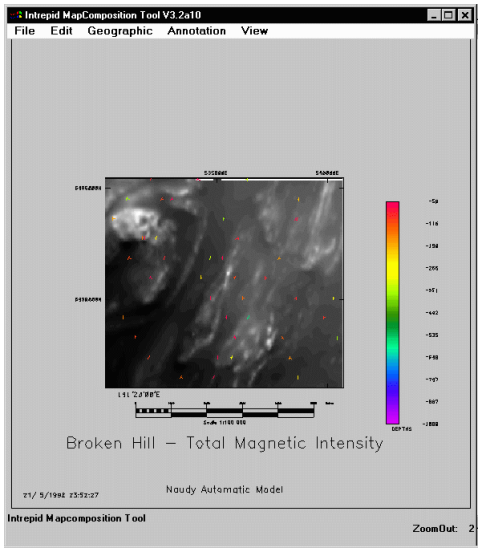
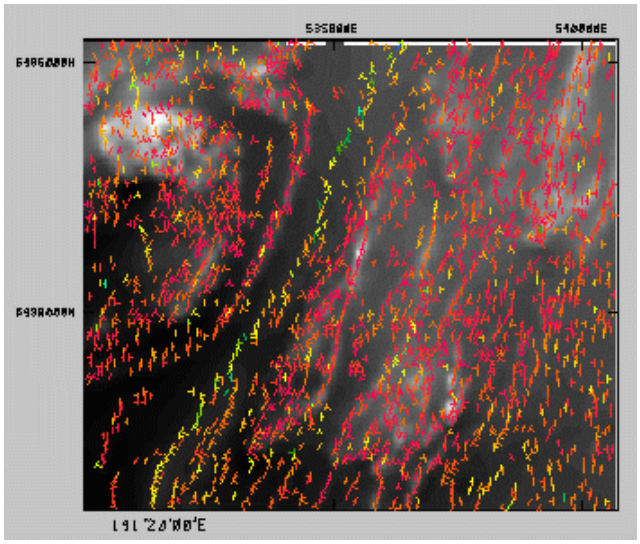
6 *Use the Hard Copy Composition tool to view the hard copy specification you created in step 19.*

From the **Print** menu, choose **Compose Hardcopy**. This will launch the Hard Copy Composition tool. Make the Hard Copy Composition window as large as possible. Open the file **`BH_TMI.map`** (a solution file provided identical to **`BH_TMI1.map`**, which you created.) Specify **Scale** 2:1 using the **View** menu.



Naudy Automatic Model (draft)



Naudy Automatic Model (full resolution, enlarged)

Tip: *The initial view of the composition is at draft resolution, showing only a few points from the Naudy Automatic Model. When you print the composition, you will see all of the points. You can increase the resolution as follows: Click the data area.Choose* **Edit Detail** *from the* **Edit** *menu.Choose* **PointPlot** *from the list of objects.Select* **Full** *from the display resolution options.You can also increase the magnification by choosing 1:1 from the* **Scale** *cascade in the* **View** *menu, then increasing the Hard Copy Composition window size.The T shaped symbols indicate the following:*

Attribute	Meaning
Colour	Depth
Direction of top (cross-bar) of T	Body strike
Length of bottom (shaft) of T	Body dip

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7 *Print the composition if you wish. (The composition is A4 size.)*

From the File menu, choose Print.

Windows version

INTREPID will launch the Print Hard Copy tool and load the composition. From the **File** menu, choose **Print Preview** to preview the plot. Then choose **Print** and respond to the conventional **Print** dialog box.

UNIX version

INTREPID displays a cascade menu with output format options. (HP–GL, PostScript, etc.). Choose the format you require. Specify a name for the output file.Print the output file in the normal way for your system.

Tip: *You can find more detailed instructions for printing and print previewing in "Printing your composition" in Map composition (G17) in the INTREPID Guided Tours.*

Repeat the steps with TMI data.

8 Repeat steps 3–24 with the 1VD data, producing shallow depth solutions.

Specify Vertical Derivative of TMI type data in step 3. Use datasets and names as follows

Function	**Dataset or Field**	**Marker file suffix (*Windows*)**
Naudy Automatic Model process		
Line dataset containing survey	**`BrokenHill`**	**`..DIR`**
Z Field for calculating Naudy model	**`1st_V_D`**	**`..LINE`**
Output Naudy model point dataset	**`BH_1vd_Naudy1`**	
Visualisation		
Solution Naudy mode point dataset for display of model	**`BH_1vd_Naudy`**	**`..DIR`**
Z field for point colour	**`Depth_Bin_No`**	**`..PNT`**
Z field for point size	**`Depth_Bin_No`**	**`..PNT`**
Grid for overlay in display of model	**`BH_1vd_grid`**	**`..GRID`**
Hard Copy Composition		
Output hard copy specification file for presenting the Naudy model	**`BH_1vd1.map`**	n/a
Solution hard copy specification file provided for presenting the Naudy model	**`BH_1vd.map`**	n/a

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When you export the model to a MAPCOMP file, use the following parameters and labels

Element	Value
Page size	A4
Orientation	**Portrait**
Scale	**100000**
Optional backdrop image	**BH_1vd_grid** (use Find Image to locate it)
Show the bodies as	**Dip Symbols** On, **Rectangle** Off
Title	**Broken Hill – First Vertical Derivative**
Subtitle	**Naudy Automatic Model**

Summary of minerals exploration worked example files

We have provided a complete set of original and solution datasets and auxiliary files with this chapter.

Installation directory

We have configured all task specification (**.job**) and hard copy specification (**.map**) files assuming that you have installed the worked example data in the directory **cookbooks** in the main INTREPID installation directory ***install_path*\sample_data\cookbooks**.

All datasets and auxiliary files associated with this chapter reside in the **interp_min** subdirectory of **cookbooks** (***install_path*\sample_data\cookbooks\interp_min**).

Original data

These datasets are the original data for the Naudy Automatic Model worked examples. The grid datasets are for display only and are not involved in the calculation.

BrokenHill	The original line dataset providing the source data
	microlevelled The magnetic data field
	1st_V_D The first vertical derivative of the magnetic data
BH_TMI_grid	Grid of the **microlevelled** field of **BrokenHill**
BH_1vd_grid	Grid of the **1st_V_D** field of **BrokenHill**

Naudy Automatic Model point datasets

These datasets contain Naudy Automatic Model solutions using the source data indicated.

BH_TMI_Naudy	Model calculated from total magnetic intensity with fixed body strike
BH_1vd_Naudy	Model calculated from first vertical derivative with fixed body strike

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Hard copy composition (.map) and associated legend (.leg) files

You can load these files into the Hard Copy Composition tool for viewing and printing the results of the Naudy Automatic Model process. Each file has an associated **.leg** file, which provides colour assignment information.

BH_TMI.map	Composition of the **BH_TMI_Naudy** Naudy Automatic Model point dataset overlaying the grey scale **BH_TMI_grid** The legend file for colours associated with depth is **BH_TMI.leg**
BH_1vd.map	Composition of the **BH_1vd_Naudy** Naudy Automatic Model point dataset overlaying the grey scale **BH_1vd_grid** The legend file for colours associated with depth is **BH_1vd.leg**

Depth estimation example (oil exploration)

This section gives specifications for a Naudy Automatic Model exercise with oil exploration data, using the data and parameters in the following table.

Note that the **northsea** dataset is located in directory **cookbooks/interp_oil**.

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Notes:

- The Naudy model point dataset creation process in this example is identical to that described in "Oil exploration interpretation case study" in Presenting regional depth and structure data (C06)
- This example does not cover the additional steps described in Presenting regional depth and structure data (C06) to prepare the dataset for the Magnetic Interpretation Example poster.
- To view the results of this example, use the procedure described in the detailed worked example earlier in this chapter.

Function	Dataset or Field	Marker file suffix (*Windows*)
Naudy Automatic Model process		
Line dataset containing survey	**northsea**	**..DIR**
Signal Field for calculating Naudy model	**mag_fin**	**..LINE**
Output Naudy model point dataset	**naudy_ns1**	
Non-default parameters: Use **Naudy-derived dips**: ON, **Line spacing 550** m, **Calculate Trends from Line** (**Note:** leave **Finishing Depth** at the default value of **10000**)		
Visualisation		
Solution Naudy mode point dataset for display of model	**naudy_ns**	**..DIR**
Signal field for point colour	**Depth_Bin_No**	**..PNT**
Signal field for point size	**Depth_Bin_No**	**..PNT**
Grid for overlay in display of model	**tmi_ns**	**..GRID**
Hard Copy Composition		
Output hard copy specification file for presenting the Naudy model	**naudy_oil1.map**	n/a
Solution hard copy specification file provided for presenting the Naudy model	**naudy_oil.map**	
WORMS, 3D Dykes		
		csv
		csv

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When you export the model to a MAPCOMP file, use the following parameters and labels

Element	Value
Page size	A4
Orientation	**Portrait**
Scale	**100000**
Optional backdrop image	**tmi_ns** (use Find Image to locate it)
Show the bodies as	**Dip Symbols** On, **Rectangle** Off
Title	**North Sea – Total Magnetic Intensity**
Subtitle	**Naudy Automatic Model**

General tips for using the Naudy depth estimation method

- The Naudy Automatic Model tool can produce variable numbers of solutions depending on the solution quality you specify. The main parameter that controls this is the **Threshold for the Similarity Coefficient**, one of the **Resampling** criteria.
- Calculate trends information from the dataset where possible. It will provide more accurate strike information for the inferred geological structures.

For shallow sources less than 200 m,

- Calculate the model using the results of the first vertical derivative (1VD). We have found that the Naudy solutions from this data are a good fit for shallow sources.
- Use the Line Filter tool to obtain the 1VD for all lines that you wish to process. Save the results as a new field in the line dataset, and use the new field for calculating the Naudy model.
- Set the **Width of Naudy Operator as a Multiple of Depth** to **1.5**. We have found that this setting picks most shallow solutions in a complex dataset and gives reasonably accurate depths (typically within 10%).

If the responses are well separated, you could increase this to **2**. This will give more accurate depths (within 5%).

- We recommend a **Naudy Threshold for Resampling** setting of **2.5** (or a value between 2 and 3) for retaining the best solutions.

For intermediate and deep sources (greater than 200 m)

- Calculate the model using the TMI. (The first vertical derivative strongly attenuates deeper responses, so is not suitable for this depth range.)
- Set the **Width of the Naudy Operator as a Multiple of Depth** to **1.5** for most situations where there is a mixture of overlapping responses.

If there are well-isolated broad responses, the depth precision will improve with a wider spacing. We have found **2** to be the optimal setting in these situations.

We recommend a **Naudy Threshold for Resampling** setting of **2.5** (or a value between **2** and **3**) for retaining the best solutions.

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Naudy Automatic Model parameters

This section contains a discussion of the parameters that you can specify for this tool, their default values and instructions about when to vary them. For more information about the parameters see Naudy Automatic Model interpretation (T43).

Parameter	Default	Notes and Variations
Resampling mode		
Geolocated **Time-based** **Fixed**	**Geolocated**	This resampling mode controls the display of data only. The Naudy Automatic Model tool has its own resampling algorithm for processing the data.
Data type		
TMI or **1VD**	**TMI**	You must specify which of these common types of data you are processing. INTREPID uses different parameters and algorithms for each.
Scanning for Naudy solutions		
Scan depth range	80–5000	The depth is measured from the observation platform. If you are examining shallow sources, we recommend that you set the starting scan depth limit to the minimum of the average clearance (aircraft height). This parameter has been found to be the most sensitive tuning parameter at your dispolsal, when it comes to scanning for shallow solutions. Just a small variation can sometimes trigger quite a different behaviour on certain lines. The starting,finishing depth and the Check box - “Finer sampling for shallow solutions”, control the total number of scan lines with depth.
Finer Sampling for shallow solutions	YES/NO	The default geometric progression is 1.2 to determine the next deeper scan line below surface. If you check this box, the progression factor is reduced to 1.05, resulting in a lot more scan lines near the surface, and so many more candidate solution from which to choose or discriminate.
Width of Naudy operator	1.5	If this is too wide, INTREPID may inadvertently introduce part of a neighbouring anomaly into the calculation. If it is too narrow INTREPID may only examine the peak of an anomaly and fail to obtain information about its true shape.

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Parameter	Default	Notes and Variations
Use Naudy derived dips?	NO	INTREPID calculates a dip for each solution. If this option is on, INTREPID will record this dip for the inferred geological structure. If it is off, INTREPID will use the dip of the scanning body. Turn this option off if • You have viewed the Naudy derived dips and they are clearly incorrect or • You require a simpler result.
Reject solutions with bad Naudy-Derived Dips?	NO	If this option is on, INTREPID will reject solutions whose dip differs by more than 30° from the dip of the scanning body. If the **Use Naudy Derived Dips** option is on, INTREPID will turn this option on, overriding any setting that you have made. If this option is turned on, INTREPID will produce higher quality solutions with more accurate depths. Turn this option off if INTREPID appears to be eliminating too many solutions for your requirements.
Calculate model for steps as well as dykes	NO	Turn this option on if you require solutions corresponding to step-like structures.
Allow negative susceptibility?	NO	Turn this off if you wish to exclude inferred geological structures with negative susceptibility. INTREPID weights negative susceptibility lower than positive susceptibility. A solution with negative susceptibility therefore acquires a higher similarity coefficient than a positive one with the same magnitude. A negative susceptibility can also indicate a strong possibility of remanent magnetization. To fit the signal, if the remanent magnetization vector was nearly 180 degrees opposite to the current inducing field vector, a negative susceptibility would result, as the only way to fit TMI data. If the signal is a full magnetic tensor gradient, this restriction does not apply, as the 2D Dyke model can be fully resolved not only for its geometry, but also the remanent vector direction.
Resampling Naudy solutions		
Threshold for similarity coefficient	2.5 (1VD)3 (TMI)	INTREPID will reject solutions whose similarity coefficients are greater than this value. The range 2–3 is suitable for this parameter. A lower threshold results in rejection of more solutions.
Minimum amplitude of corresponding anomaly in observed field	.001 nT (1VD)1 nT (TMI)	The default value corresponds to typical noise amplitude in magnetic data. Anomalies with less than this amplitude are likely to be noise rather than useful data. If you know that you have low amplitude anomalies, such as in a basin area, you can reduce the value of this parameter

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Parameter	Default	Notes and Variations
Creating the Naudy model		
Line spacing	200 m	You must set this to the acquisition line spacing in the input line dataset. It determines the length of the inferred geological structures in the model. It does not affect the trend calculation process, which has its own line spacing measurement system.
Refining the Naudy model		
Number of iterations	20	This parameter determines the number of inversion iterations INTREPID will perform. Reduce the value to, say, 10: • To speed up process, or • If you have found that the inversion results are unstable and you are obtaining clearly incorrect results.
Invert when processing lines	NO	If you turn this option on, INTREPID will automatically include the inversion process when it creates the model for the dataset. It will vary the properties of each inferred geological structure for a better fit of the calculated field to the observed field. Inversion will tend to smooth out small anomalies in the data, providing a better overall picture of the dataset. Without inversion the Naudy Automatic Model tool will fit small anomalies more closely. Turn the option off : • For faster processing OR • If a simple set of solutions are adequate OR • If you do not wish to smooth out smaller anomalies.
Body strike calculation		
Body strike options	Perpendicular to line direction	If you do not want to calculate trend information (faster process), use the default setting. If you are aware of a general trend in the dataset, specify a fixed body strike (0 = North–South). The Trend Dataset method is now obsolete. Contact our technical support service for information if required. We recommend that you normally calculate trends from the line data.

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Parameter	Default	Notes and Variations
Filters	Use shallow and deep trend filters provided	INTREPID calculate trends at different depths. To obtain data applicable to a depth, INTREPID applies an appropriate filter. The filters provided for TMI are: **Shallow**: residual of 51-point local mean **Deep**: 300 m upward continuation **Very deep**: 5000 m upward continuation Contact our technical support service for further information. You can design your own filter as described in Line Filtering (T31)
Dimensions of search rectangle	3.5 across 3.0 along	(measured in line spacings) This is the size of the area within which INTREPID associates minima and maxima on adjacent lines to detect trends. INTREPID automatically estimates line spacing for this process.
Maximum angle for connecting trends	25	For example, lines A and B may have maxima close within the search rectangle and line C also may have a maximum within the rectangle.If lines drawn between the A–B maxima and the B–C maxima are at an angle of less than the size specified here, then INTREPID assumes than the three maxima are part of the same anomaly. INTREPID will assign a strike matching the angle to inferred geological structures in this area. If you decrease the angle, INTREPID will be more stringent in detecting trends. If you increase it, INTREPID will be less stringent.

Protobuf Data Model

At V5.0, Intrepid has published the full datamodel for this tool, including examples of how to set values and options. The example is to be found under the Examples/Task/Naudy directory.

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